

5

Smoking career

Abstract

In spite of the overwhelming evidence of the harmful effects of cigarette smoking, little is known about how smoking evolves over the life course. In this chapter, we have taken a novel approach to analyze the “career or pattern over time” of smoking in a well-documented population. The objective of this chapter was to analyze smoking status throughout life and translate it into life years lived in a smoking and non-smoking state. Multistate life tables were developed to capture the life history of smoking. The data were obtained from the Framingham Heart Study (FHS), which has a 48-year follow-up of 5,209 respondents residing in Framingham, Massachusetts, ranging in age from 28 to 62 years at the baseline survey between 1948-1951. Three states {smoking, non-smoking, dead} were distinguished. We defined smokers as individuals who were recorded as smoking at any given examination and non-smokers as those who were recorded as non-smoking at that examination. The smoking status recorded at each examination throughout the 48 years of follow-up of the FHS formed the basis for age-specific transition rates between smoking states.

At age 10, the total life expectancy of the FHS cohort was 66 years for males and 72 years for females. Males were shown to spend two-thirds of their expected lifetime (68%) smoking, females less than one third (28%). The difference was less at higher ages, by which time males with a history of smoking had either quit or died. The smoking careers of males started 2 years earlier than that of females. The average age (median age) at which males started smoking was 15, for females, 17. Fifty-eight percent of the males who started smoking did quit at some point, while for females this proportion was considerably lower, namely 37%. Compared to men, women smokers were more persistent. If a person quit smoking, they were most likely to do so between the ages of 50 and 70. After quitting smoking, a certain percentage will resume the habit over time. The probability of a relapse was 26% for both males and females. The novel approach described here demonstrated the usefulness of multistate life tables for describing how smoking evolves over the life course. While we cannot assume that similar patterns apply to other

populations, the method can be used for other risk factors to indicate current risk factors in life courses.

5.1 Introduction

Cigarette smoking was once so common that to imagine a world without it was difficult. Nevertheless, for thousands of years, consistent tobacco use was not the norm: in fact, such high prevalence and regular consumption are historically unusual. Today, the adverse health consequences of smoking is widely recognized (Peto et al., 1992; 1994; 1996; Doll et al., 1954; 1956; 1964; 1976; 1994; 1998; Thun and Heath, 1997; Surgeon General, 1964; 1979; 1989; 1990; Royal College of Physicians, 1962; 1971; Fielding, 1985). However, smoking remains the number one cause of preventable death in developed countries and it continues to be the largest single preventable cause of death and disability in the United States (Center for Disease Control and Prevention (CDC), 2001). The millions of lives that tobacco claims each year makes tobacco one of the most important public health issues of the present time (Bartecchi et al., 1994). Globally, an estimated 3 million people die from smoking-related disease each year (Peto et al., 1996). Tobacco causes 1 in 4 deaths in developed countries, 1 in 8 deaths in developing countries and 1 in 6 deaths worldwide (Barnum, 1994). Another study estimated that smoking may account for 25 percent of all deaths (Shopland, et al., 1990; Crimmins, 1981), 30 percent of all coronary heart disease deaths and for about 30 percent of all cancer death, counting 85 percent of all lung cancer deaths (American Cancer Society, 1986). Within 30 years, the number of global tobacco-related deaths will rise to 10 million per year, and tobacco will become the single largest cause of death worldwide (World Bank, 1999). However, very little research has targeted the smoking career on an empirical basis. The objective of this chapter was to analyze smoking status throughout life and to translate this into life years lived in the smoking and the non-smoking state.

Epidemiology and medical demography study the impact of risk factors on chronic diseases. Many risk factors are time varying. Smoking is a very important risk factor and a major preventable cause of morbidity and premature death. The hazards of smoking have been documented by many studies (Doll et al., 1954; 1956; 1964; 1976; 1994), which have been summarized by the Royal College of Physicians, (Royal College of Physicians 1962; 1971), the United States Surgeon General, (Surgeon General, 1964; 1979; 1989) and the International Agency for Research on Cancer (IARC monographs, 1986). To determine the risk and hazard of smoking associated with morbidity and mortality, researchers have in the past applied survival analysis to calculate the relative risk and the smoking attributable risk of mortality (cause specific or all cause combined) (Rogers et al., 2002),

generally based on smoking status at a single point in time. In this chapter, we have taken a novel approach towards the analysis of the “smoking career or pattern over time” in a well-documented population. Less is known about the career of smokers. The well-known Framingham Heart Study afforded us with a unique opportunity to calculate the smoking career of a cohort of 5,209 people that has been followed since the middle of 1948. Some 48 years of follow-up of the smoking history of that cohort were available to us.

Despite various studies over the past 40 years, only a few studies have focused on the life expectancies of smokers and non-smokers (Miller and Gerstein, 1983; Rogers and Powell-Griner, 1991; Doll et al., 1994). However, to our knowledge there has heretofore been no approach that studied smoking status throughout life. There are several reasons for this: in the first place, most of the researchers used cross-sectional information, which meant that only the current smoking status was recorded; second, individuals have started smoking at increasingly early ages, and the effect is cumulative, largely between age 35-70. Gathering information on the age at which an individual starts smoking, quits or switches their smoking habits and on smoking behavior (e.g. style of smoking) over the life course is difficult. In the third place, their small sample size, local population base and emphasis on one smoking status rather than a range of statuses have limited many studies.

The studies calculating life expectancies of smokers and non-smokers by sex, used separate single decrement life tables (alive and dead state) for smokers and non-smokers (Miller and Gerstein, 1983; Rogers and Powell-Griner, 1991; Doll et al., 1994). The shortcomings of this approach included the use of smoking prevalence i.e. smoking status at a specific point of time. Chiefly, these studies considered the smoking status before death or any other event (e.g. lung cancer). Using this method, the current smoking status of a real population, adjusted for mortality levels, was reflected. It may therefore not represent the lifetime smoking status at the level of the individual. These studies used prevalence or stock data instead of incidence or flow data, and avoided reverse transition, i.e. non-smoking to smoking or smoking to non-smoking. The resultant estimation was mainly for the overall population. In our approach, we minimized all these restrictions. We used smoking incidence, which is measured over a long period of time. We focused on flows instead of stocks. Back flow, too, was captured. When, analyzing the life histories of smokers and non-smokers, we were therefore able to translate smoking status into life years lived in a smoking and a non-smoking state within a synthetic cohort.

We constructed a multistate life table to investigate the smoking career. Some of the life course questions that the multistate smoking status life table was able to answer were: what proportion of lifetime is spent by individuals as smokers? What is the lifetime probability of quitting smoking? If people quit smoking, when do they quit? Male-female mortality differs among smokers (Waldron, 1986). Does the

smoking career of a male differ from that of a female? We answered these questions, applying multistate life table techniques to the life histories of smokers and non-smokers in the FHS original cohort. The FHS study offers a unique historical documentation of fifty years of health damage due to smoking.

Section 5.2, in which the proposed method is illustrated, consists of a number of: data source, smoking status definition, imputation of missing smoking status, model specification, the input data and the life table construction. The results are given in Section 5.3. Section 5.4 concludes this chapter following a brief discussion.

5.2 Methods

We constructed smoking status life tables focusing on transitions between smokers and non-smokers in the first 48 years of follow-up from the Framingham Heart Study original cohort. Smoking prevalence at different times of follow-up, smoking episodes, survival probability, life expectancies in smoking and non-smoking state and lifetime probability of quitting smoking were considered separately for males and females.

The following subsections describe the data source, the definition of smoking status, imputation of smoking status, the input data and the construction of the multistate smoking status life table.

5.2.1 Data source

The data used for this study came from the Framingham Heart Study original cohort. The Framingham Heart Study is a well-known, epidemiological ongoing longitudinal study focusing on cardiovascular disease. The Framingham Study was designed to find out how those who develop cardiovascular diseases differ from those who remain free of the diseases over the life course in order to identify risk factors for cardiovascular disease. The original study cohort consisted of 5,209 respondents (45 percent male) from a sample of adults aged 28 through 62 years residing in Framingham, Massachusetts between 1948 and 1951. The participants were tracked by standardised biennial cardiovascular examination, daily surveillance of hospital admissions, death information and information from physicians and other sources outside the clinic, ensuring highly accurate follow-up of death and clinically presenting cardiovascular disease. Among other characteristics, the smoking status of the participants was recorded at each examination. Details of the FHS are documented elsewhere (Dawber and Moore, 1952; Shurtleff, 1971). For the current study, we used the data regarding smoking status over 48 years of follow-up (exam rounds 1 to 24) of the FHS original cohort.

5.2.2 Smoking status

The smoking status of the FHS respondents was recorded on the basis of the responses to two questions. Participants were asked whether they currently smoked (yes or no) and about the number of cigarettes smoked within 24 hours. The first is a binary variable, the second a count variable. To characterize the pattern of smoking over time and the effect of smoking on mortality, our definition of smoker versus non-smoker at any point in time took into account the smoking history recorded in each exam. “Smokers” were individuals recorded as smoking at a given examination and “non-smokers” were those who were recorded as non-smoking in that examination. The smoking status is therefore time varying and up-dated.

At the first exam, all current smokers were asked ‘at what age’ they had started smoking. At that exam, all ever-smokers were also asked when they had relapsed back into smoking. Some ever-smokers were not able to indicate when they had started. As we were interested in constructing the smoking career, the respondents whose starting time of smoking was unknown were excluded (277 respondents). Smoking has the tendency to start at early ages. We assumed all participants were non-smokers at age 10, i.e. smoking initiation was possible from age 10 onwards. In the FHS, a few individuals had started smoking even before the age of 10 (45 respondents). For the purpose of this study, we assumed that these individuals had started at age 10. We moreover excluded respondents who had cardiovascular disease at the first exam (139 respondents), while smoking status was missing for 27 respondents at the first exam and 72 respondents were lost to follow-up. Finally, we were left with 4694 (43 percent males) participants whose smoking careers we proposed to investigate.

5.2.3 Missing value imputation

The aim of this chapter was to construct the smoking career of the Framingham Heart Study cohort. Smoking status data was collected biennially on the FHS participants. Over the long period of follow-up, there were several exams at which smoking status was not recorded. For instance, no data on the smoking status of the respondents was collected at exams 2, 3, 6 and 16. Sometimes respondents were present at an exam without their smoking status being recorded. Without imputation of the missing values, construction of the smoking career was not plausible, nor would we be able to follow the smoking career of various individuals. We therefore imputed the missing values of the smoking status.

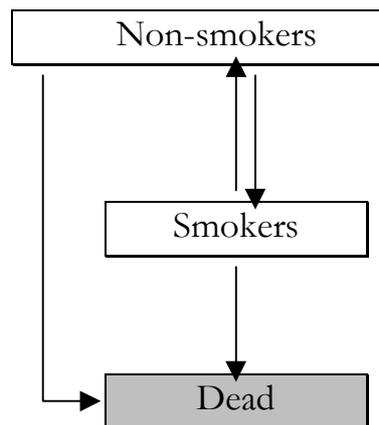
We imputed smoking status essentially assuming that changes in smoking status occurred midway through an unobserved period and that imputation was only allowable for values 2 years or less (i.e. 1 round) from a recorded value. Thus if smoking status was known at an exam prior to a missing value, this value was

imputed forward. If a value was not available from the exam prior to the missing value the value from the next exam was imputed backward. If a missing value was surrounded by two other missing exams, it was not imputed and remained missing. For details of the imputation method and the values after and before imputation, we refer to Chapter 4, Section 4.4.

5.2.4 Model specification and input data

We constructed a 3-state multistate smoking status life table. The state space was {smoking, non-smoking, dead}. Smoking and non-smoking were communicable states and dead was an absorbing state. For instance, at age 30 a male could be a smoker; the same man could be non-smoker at age 50 and a smoker again at age 65, to become a non-smoker once again before death. Here, we have used the updated smoking status.

Figure 5.1 Model specification



The age-specific occurrences (event counts) and exposures were the basic input data for the multistate smoking status life table. Since smoking status was recorded at each biannual exam, we assumed that a transition from non-smoking to smoking or smoking to non-smoking would occur midway between two exam dates. Transition to death was recorded at the exact date. Both the occurrences and exposures were calculated using the approach described in Section 3.3.3 of Chapter 3. We estimated occurrences and exposures separately for the total population, for males and for females.

5.2.5 Multistate life table construction

The multistate smoking status life tables were constructed based on the age-cohort observational plan (Willekens, 1987). The calculation of occurrence-exposure rates, the conversion into transition probability and other life table statistics were described briefly as follows.

To construct the life tables, it was necessary to convert the transition rates $M_{ij}[x, x+1)$ (see equation 2.10 in Chapter 2) into transition probabilities. The transition rates were converted to probabilities for use in the life table by assuming that within an age interval (one-year), the transitions (events) were uniformly distributed. Following the standard approach suggested by Rogers (1975; 1995) and Willekens et al. (1982; 1987), the transition probability matrix $\mathbf{P}[x, x+1)$ was calculated from the matrix of occurrence-exposure rates, $\mathbf{M}[x, x+1)$. The transition probability matrix $\mathbf{P}[x, x+1)$ can be calculated from the transition rate matrix $\mathbf{M}[x, x+1)$ using:

$$\mathbf{P}[x, x+1) = [\mathbf{I} + \frac{1}{2} \mathbf{M}[x, x+1)]^{-1} [\mathbf{I} - \frac{1}{2} \mathbf{M}[x, x+1)]$$

where \mathbf{I} is an identity matrix of order as of $\mathbf{M}[x, x+1)$ matrix. Using the 3-state model (Figure 5.1), the multistate model of the 3x3, a matrix of transition rates was specified as:

$$\mathbf{M}[x, x+1) = \begin{pmatrix} M_{11}[x, x+1) & -M_{21}[x, x+1) & 0 \\ -M_{12}[x, x+1) & M_{22}[x, x+1) & 0 \\ -M_{13}[x, x+1) & -M_{23}[x, x+1) & 1 \end{pmatrix}$$

where the suffix 1 stands for current smoker; 2 currently non-smoking and 3 is dead. The diagonal elements $M_{ii}[x, x+1)$ were calculated from the non-diagonal entries on the condition that the sum of entries over the destination status was zero.

The probability that a person was not a smoker at exact age x was-

$$l_{nsm}(x+1) = l_{nsm}(x) * [1 - q_{nsm,sm}[x, x+1) - q_{nsm,d}[x, x+1)] + l_{sm}(x) * q_{sm,nsm}[x, x+1)$$

Similarly, the probability that he or she was a smoker was-

$$l_{sm}(x+1) = l_{sm}(x) * [1 - q_{sm,nsm}[x, x+1) - q_{sm,d}[x, x+1)] + l_{nsm}[x, x+1) * q_{nsm,sm}[x, x+1).$$

Assuming the transitions occurred in the middle of the age interval, the life table exposure was calculated using the formula,

$$L_i[x, x+1] = 0.5 * [l_i(x) + l_i(x+1)]$$

All life tables were constructed from age 10 on, with the last at age 95 being open-ended. For the oldest open age group (in this case age 95 and above), the following formula could be used:

$$M_i(95+) = 1/e(95+), \text{ for } i=1,2$$

Both for males and females, we assumed that mortality rates after age 95 were constants irrespective of smoking status. We used the Massachusetts States Life Tables (Centers for Disease Control and Prevention, 1988-91). For males $e(95)=2.92$ years, for females $e(95)=3.40$ years., and 3.29 years for the total population. Using the life table formula in stationary population, we found that $M(95+)=1/2.92=0.34$ for males, and $M(95+)=1/3.30=0.29$ for females. We also assumed no mortality prior to age 30.

The total number of person-years lived was calculated using the formula,

$$T_i[x, x+1] = \sum_{t=10}^{95+} L_i(t)$$

Life expectancy at age x was, $e_i(x) = T_i[x, x+1] / l(x)$, where $l(x) = l_{nsm}(x) + l_{sm}(x)$.

5.3 Results

The aim of this chapter was to analyze the smoking career. For this purpose, we constructed a multistate smoking status life table. Before describing the results of the multistate smoking status life table, we described the different episodes of smoking and changes in smoking status over 48 years of follow-up of the FHS. We obtained the life expectancy, survival of the cohort, lifetime probability of quitting smoking and differences in the number of years lived by smoking status from the multistate smoking status life table. As smoking initiation, quitting, switching and health effects are different between males and females (Prescott et al., 1998; Marang-van de Mheen et al., 2001), we presented the results separately for males and females.

5.3.1 Changes in smoking status

The changes in smoking status of the FHS cohort at different points in time (after each 10 years of follow-up of those people who survived and reported their smoking status) are presented in Table 5.1. At study entry (1948-51), 86 percent of males and 43 percent of females were smokers. This prevalence was slightly higher compared to the smoking prevalence at the first exam reported in Chapter 4, as we excluded the respondents who reported that they had quit smoking before entry into FHS. As expected, the prevalence of smoking declined for both males and females over time. After 40 years of follow up, the prevalence of smoking fell from 86 percent to 9 percent for males and from 43 percent to 10 percent for females. Smoking prevalence declined more sharply among male smokers compared to females. Smoking prevalence was shown to decrease an average of 20 percent for males and nearly 10 percent for females per ten years of follow-up. During 48 years of follow-up, 83 percent of male participants and 72 percent of female participants died.

Table 5.1 Smoking prevalence (%) at different time points of follow-up, FHS

	Male %	Female %	Total % (N)
At first exam			
Smoking	86	43	61 (2872)
Non-smoking	14	57	39 (1822)
After 10 years of follow-up			
Smoking	72	39	52 (2012)
Non-smoking	28	61	48 (1833)
After 20 years of follow up			
Smoking	49	28	36 (1096)
Non-smoking	51	72	64 (1928)
After 30 years of follow up			
Smoking	30	20	24 (442)
Non-smoking	70	80	76 (1404)
After 40 years of follow up			
Smoking	9	10	10 (118)
Non-smoking	91	91	90 (1105)

5.3.2 Smoking episodes

We assumed that at age 10, all participants (4694) were non-smokers. However, of the 2013 non-smoking males at age 10, 1759 (87%) had experienced at least one episode of smoking. Of the 2694 females, 48% had experienced at least one

episodes of smoking during follow-up. Among males, 13% (females 8%) had experienced more than two episodes of smoking. At a certain age, they initiated smoking, then quit only to take up the habit again. Among male smokers, at least 48 percent quit smoking. At least 31 percent of female smokers quit. Of all first-time quitters, both male and female, almost 26 percent restarted smoking.

Based on biannual reporting of smoking status over 48 years, the FHS cohort was found to have experienced total 10,485 episodes, of 6880 episodes (66 percent) of non-smoking and 3605 (34 percent) episodes of smoking. Males experienced 39 percent of smoking episodes and females experienced 30 percent of smoking episodes.

Table 5.2 Total number of smoking and non-smoking episodes based on biannual reporting of smoking status over 48 years of follow-up of FHS

	Non-smoking episodes (%)	Smoking episodes (%)
Total	6880 (66)	3605 (34)
Male	3203 (61)	2152 (39)
Female	3677 (70)	1548 (30)

5.3.3 Transition rates

The empirical age-specific¹ transition rates by smoking status are shown in Figure 5.2. In the FHS, the mean (median) age of initiation of smoking was 16 (15) years for males and 18 (17) years for females. Overall, from age 30 to 70 the rate of transition from non-smoking to smoking remained stable. Most restarters were in this age band. Smokers started quitting at age 30; the number of quitters was shown to increase after age 50 and to remain high until age 74. Cessation of smoking subsequently leveled off after age 75.

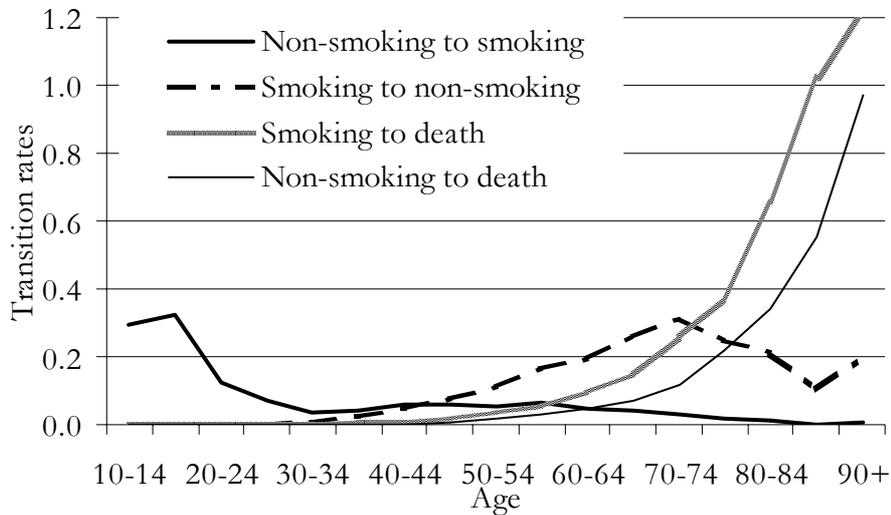
At age 15 or 16, the rate of initiation of smoking was nearly 0.7 for males and 0.2 for females. Males tended to start smoking at early ages. Females started smoking between the ages of 12-20. The rates of restarters among males were twice that of females. The pattern of quitting smoking was nearly the same both for males and females. Starting at age 30, cessation levels increased from age 50 and continued until age 74 after which stabilization occurred.

¹Age-specific transition rates are plotted for 5-year age band instead on one year age band to avoid the irritated behavior of transition rates

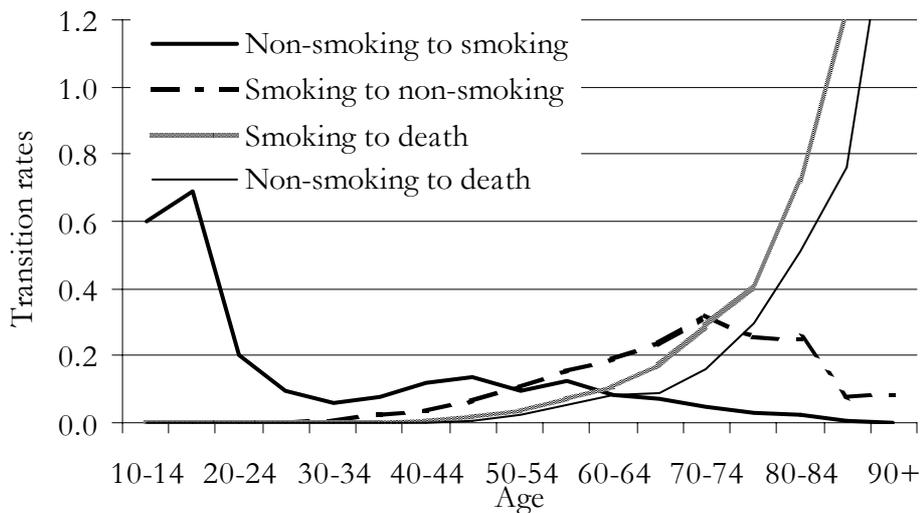
As expected, the age-specific death rates for male and female smokers were higher than for non-smokers. Compared to males, the differences in mortality rates by smoking status were higher among females. This could be why smoking has been shown to be more harmful to females than to male smokers (Marang-van de Mheen et al., 2001; Surgeon General, 2001; Dresler, 1998). The zero mortality rate prior to age 30 was a model input, as mortality follow-up did not begin until age at entry into observation (minimum age at entry into observation was 28).

Figure 5.2 Transition rates by smoking status

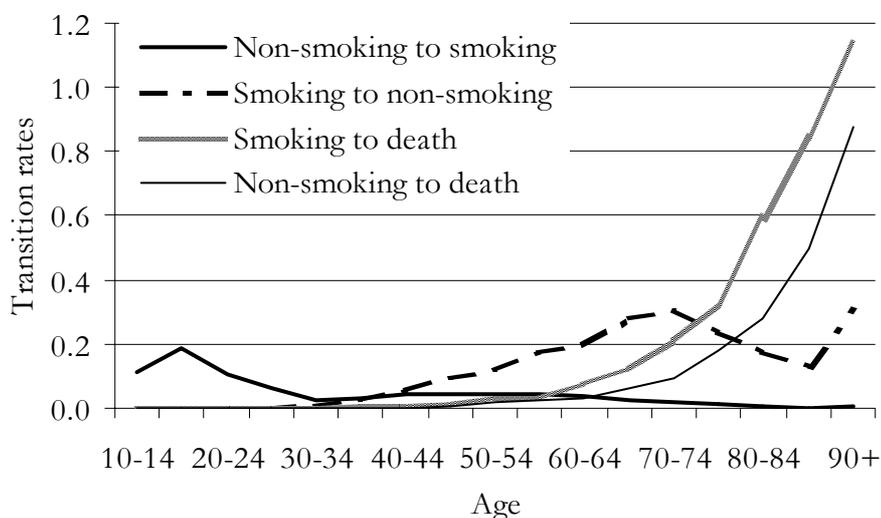
Male and female



Male



Female



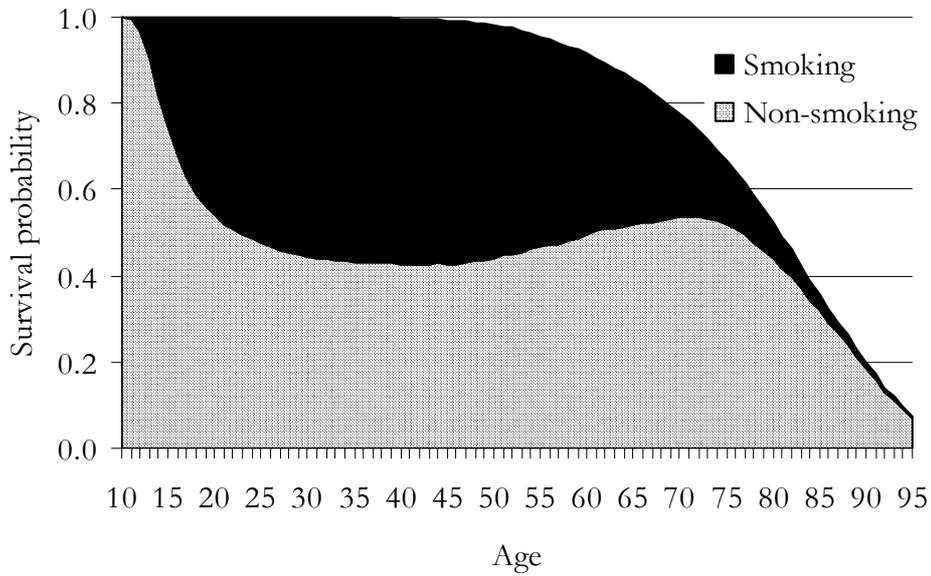
5.3.4 Survival probability

The survival probabilities or state occupancies of male and female smokers and non-smokers are presented in Figure 5.3. This survival curve demonstrates the survival proportion of a synthetic cohort with a particular smoking status. It pictures how smoking evolves over the life course. The lower portion represents the probability of being alive at that age and being a non-smoker. The upper portion represents probability of being alive and a smoker.

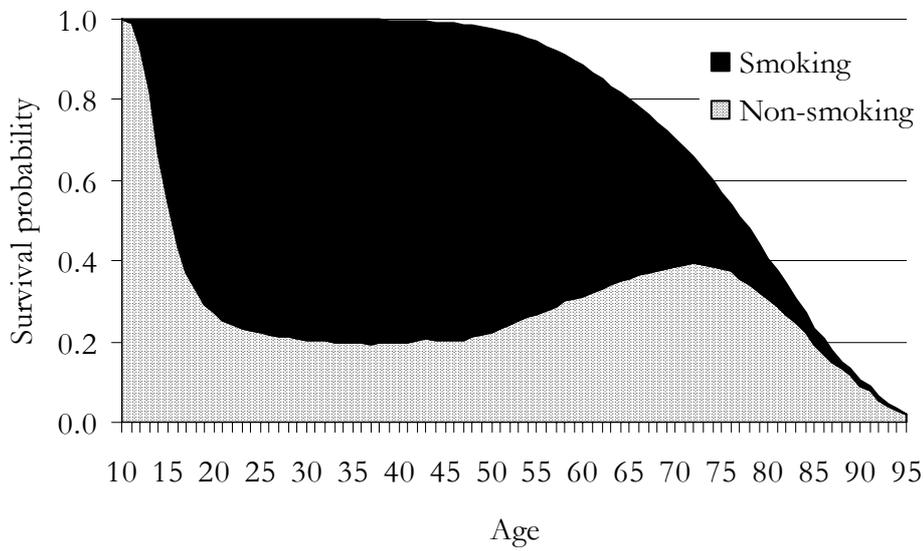
The survival probabilities may be used to determine interesting conditional probabilities. For instance, the probability of a 10-year old non-smoker being a non-smoker at age 25 was nearly 50 percent (25 percent for males and 70 percent for females). The survival probability in non-smoking state was the lowest at age 45 (43 percent). The probability of survival in a non-smoking state increased until age 75, after which it leveled off. Non-smokers were seen to survive longer and smokers to die prematurely.

Figure 5.3 Survival probability in a non-smoking state and survival probability in a smoking state of a cohort of 10-year-old males and females of FHS

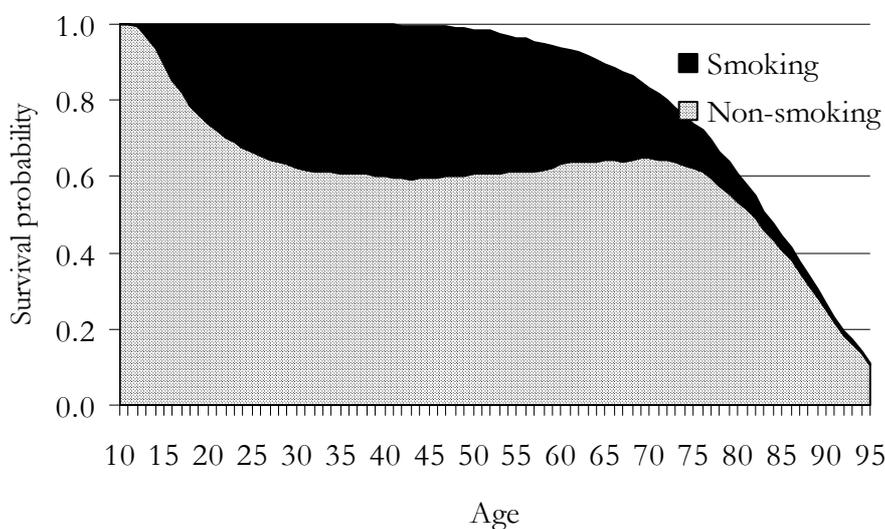
Total population



Male



Female



5.3.5 Life expectancy

We used the transition probabilities estimated from the FHS to calculate the expected number of years in each smoking status. The multistate life table translates the age-specific transition probabilities in dwelling times or number of years spent as a smoker and as a non-smoker. We estimated the expected dwelling times in each smoking status for reference ages 10, 30, 50 and 70. The FHS recorded the age at which respondents started smoking. Although 45 persons started smoking before or at age 10, they were assumed to have started at age 10, implying that everyone was a non-smoker at exact age 10. Table 5.3 shows the dwelling times.

The life expectancy at age 10 was 69.13 years (65.71 for males and 71.66 for females). Males smoked for considerably more years than females. A male of age 10 could expect to spend 41.13 years as a smoker, which was 63% of the expected lifetime. Females of the same age could expect 19.97 years as smokers, which was 28% of the remaining lifetime. At age 50, the picture was quite different. Males of that age could expect to spend 53% of the remaining lifetime as smokers (13.91 years of the expected total of 26.46 years). Fifty-year old females smoked 24% of the remaining years. This was an interesting observation. Although when younger, the share of remaining life in which an average male smoked was considerably larger than that of an average female, the difference was relatively small at age 50 and was further reduced at higher ages. The change may be attributed to two factors. The first is quitting behavior. Males were more likely to quit smoking than females and they quit at an earlier age (see Section 5.3.6). Second, and more importantly, is the selection factor. Males with a history of smoking died at a younger age than males who had never smoked. As a result, their share in the older male population was smaller.

Table 5.3 Number of years that a person of a given age and sex may expect to spend in each smoking status, FHS

	Life expectancy at age			
	10	30	50	70
Total life expectancy	69.14	49.14	29.76	14.38
Years spent non-smoking	40.11	27.64	19.35	11.78
Years spent smoking	29.03	21.50	10.41	2.60
Difference	11.07	6.14	8.93	9.17
Males				
Years spent non-smoking	24.58	16.29	12.55	8.54
Years spent smoking	41.13	29.42	13.91	3.53
Difference	-16.55	-13.13	-1.36	5.01
Females				
Years spent non-smoking	51.69	36.09	24.34	13.76
Years spent smoking	19.97	15.56	7.83	2.03
Difference	31.72	20.53	16.52	11.73

5.3.6 Lifetime probability of quitting smoking

One of the useful features of the life table technique is that it can be used to calculate the lifetime probability of an event. For example, we are aware that many smokers quit smoking. What is the probability that an individual, who was smoking at age 20, will quit smoking before age 40, 60 or death? The probabilities of quitting smoking at different ages are presented in Table 5.4. Smoking cessation has immediate and substantial health benefits, both symptomatically and pathophysiologically, and dramatically reduces the risk of most smoking-related diseases (Office of the U.S. Surgeon General, 1989).

For the synthetic cohort derived from transitions within the Framingham cohort, the probability of quitting smoking before age 50 was 10 percent. Before age 70 it was 37 percent and before death it was 46 percent. More than 50 percent of the smokers did not quit smoking during their lifetime. Those who quit were more likely to do so between the ages of 50 and 70 than at any other age. The lifetime probability of quitting smoking for males and females of the FHS participants was 58 percent and 37 percent, respectively. Before age 50, it was 12 percent and 8 percent, respectively. By the age of 70, nearly half of the men had quit smoking. By age 70, only 30 percent of the females had quit smoking. The percentage of females quitting smoking over the life course was 21 percent lower than males.

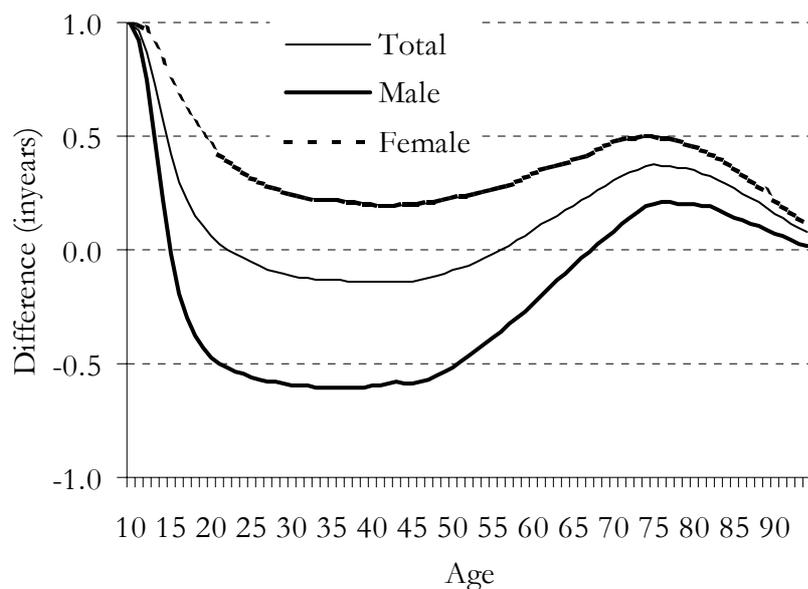
Table 5.4 Probability of quitting smoking

	Probability (%) of quitting smoking before age				
	40	50	60	70	Death
Total population	2	10	23	37	46
Males	3	12	29	47	58
Females	2	8	19	30	37

5.3.7 Person-years lived by smoking status

This study measured the life history of smoking and non-smoking in terms of the differences in the life-table person years lived in smoking and non-smoking states. The age-specific person years lived in the non-smoking status were subtracted from the age-specific person years lived in the smoking status (Figure 5.4). This approach allowed us to gauge the differences in the age-specific person-years lived by smoking status (for details, see Section 2.4.7). A negative difference (non-smoker-smoker) meant that an individual spent more time in the smoking state at that age interval. Overall, the synthetic FHS cohort spent more time in the smoking state in the age band 22 to 55 compared to the non-smoking state. Males between the ages of 15 and 65 spent more time in the smoking state than as non-smokers. However, throughout life, female participants spent more time in the non-smoking state than in the smoking state.

Figure 5.4 Differences of the person-years lived: non-smokers–smokers



5.4 Discussion

We have presented an analysis of the smoking career of a white American population, namely the original Framingham Heart Study cohort. We observed their smoking experiences throughout life and translated the smoking status into life years lived as a smoker and non-smoker within a synthetic cohort. Overall, the FHS cohort experienced longer life in a non-smoking state than in a smoking state. Male participants spent more time as smokers between the ages of 15 and 65 than as non-smokers. Females spent more time in a non-smoking state than smoking state. Using the FHS cohort, we found that less than half of smokers quit smoking during their lifetime.

The smoking career of the male participants was different from that of a female participant. Men usually initiated smoking at an early age (2 years earlier), which was consistent with the present generation. Among male smokers, at least 48 percent quit smoking. At least 31 percent of female smokers quit smoking. Of male non-smokers at age 10, only 1 in 5 remained a non-smoker and 4 in 5 initiated smoking before age 25. Similarly, among female non-smokers at age 10, about 2 in 3 remained non-smokers and 1 in 3 initiated smoking before age 25. Compared to men, women smokers were more persistent. The restarting rate was twice as high among males compared to females. The probability of relapse was 26 percent for both males and females.

The important findings of this chapter are the life course indicators: life expectancy in a non-smoking state and life expectancy in a smoking state, the lifetime probability of quitting, and the differences in person-years lived by smoking status. At age 10, the total life expectancy of the FHS cohort was 66 years for males and 72 years for females. Males spent two-thirds of their expected lifetime (68%) smoking. This was less than one third for females (28%). The difference declined at higher ages when males with a history of smoking either quit or die. A female expected to survive more years as a non-smoker than in the smoking state.

The lifetime probability of quitting smoking for males and females of the FHS participants was 58 percent and 37 percent, respectively. Over the life course, the percentage of females that quit smoking was 21 percent less compared to males. More than 50% of smokers did not quit smoking in lifetime; individuals who quit were more likely to be between the ages of 50 and 70. Females were more persistent smokers, which could explain why smoking is more harmful to female smokers. There could be other possible causes, such as smoking intensity in terms of number of cigarettes smoked or hormonal changes. However, evidence shows that female smokers are at much greater risk of lung cancer than men (Risch et al., 1993; Dresler, 1998).

The strength of the present chapter lies in its focus on a well-documented epidemiologically defined community-based population and a 48-year prospective

consistent follow-up of the same cohort. Such a long-term monitoring of a large cohort enabled us to investigate the initiations, patterns of quitting, restarting and to characterize the individual smoking career. However, these findings are highly period and place specific. They are limited to the American population that started smoking in first half of the last century. Another strength of this chapter was the novel approach to analyzing the smoking career. Our smoking status definition included the up-dated information on smoking status rather than the status at a specific point in time i.e. we used incidence of smoking. We defined smoking status explicitly.

The importance of the described method is at least threefold.

Firstly, a knowledge of the historical smoking and quitting patterns is important for the interest taken by current studies in the cumulative smoking histories of current populations. The smoking career of today's generation will differ from that of the generation of the mid-1950s. For instance, prevalence of smoking was highest after World War 2, which might reflect the quitting effect. Female prevalence and consumption of smoking increased after the 1980s and women started smoking more like men (Doll et al., 1994). A recent report by the Surgeon General shows that prevalence of smoking is increasing among teenage girls compared to boys (Surgeon General, 2001). Today's persistent smokers may well have smoked a substantial number of cigarettes throughout adult life, whereas few of the smokers during the period 1950s can have done so (Peto et al., 2000). Therefore the smoking career of the present generation will be different than the past generation. However, lifetime smoking exposure of older generations now is based on these historical measures, so it also has current relevance.

Secondly, several life course indicators, such as expected years lived in a non-smoking and a smoking state, lifetime probability of quitting smoking and the differences in the time spent by smoking status are the new indicators among the public health community.

Thirdly, this method can be used for other risk factors to indicate current risk factor life courses.

Our novel approach demonstrates one way of explicitly taking into account the changes in risk factors throughout life. However, our approach is data demanding. For the life course analysis of other risk factors, for instance to construct the cholesterol career, hypertension career, obesity career, diabetes career and so on, epidemiologists and medical demographers can use this method in more innovative ways than any other methods. Since smoking is the major preventable cause of premature death, we need further insights into the smoking career of the present generation. To do so, our approach could be a standard one.

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